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9th International Symposium on Cavitation (CAV2015) IOP Publishing
Journal of Physics: Conference Series **656** (2015) 012179 doi:10.1088/1742-6596/656/1/012179

Experimental study of the thermodynamic effect in a cavitating flow on a simple Venturi geometry

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Abstract. The thermodynamic effects in cavitating flow are observed on a simple Venturi profile. A thorough experimental investigation of the temperature field on cavitating flow has been performed in water of 100°C at different operating conditions. Temperature measurements were performed with Infra-Red (IR) high-speed camera, while visualisation was made with conventional high-speed camera. Both, average temperature fields and temperature dynamics are presented at different operating conditions and compared with collected data in visual spectrum. In the vicinity of the throat a temperature depression up to 0.5 K was recorded.

1. Introduction

Cavitation is a physical phenomena simply described as a growth and collapse of multiple small vapor bubbles within a liquid by approximately constant temperature. While an exact process of cavitation development is still not fully understood and scientifically described, it is assumed that cavitation is mainly a process of vaporization by cavity growth and condensation by cavity collapse, which is a consequence of heat transfer and temperature divergence between the bulk liquid and vapor + gas inside the cavitation bubbles. Dealing with liquids like cold water, the local temperature variations caused by cavitation can be neglected, while this must not be the case in liquids, which operate close to its critical point (cryogenics), where the temperature variations are big enough to affect the cavitation development – these phenomena are described as thermodynamic effects.

Experimental studies of these phenomena are rare and most of them only observed the integral consequences (cavitation delayed inception and reduced extent) of the presence of the thermodynamic effects. Hord et al. [1-4] have made an extensive experimental observation on different geometries in liquid cryogens, while observing cavitation inception and extent at different operating conditions. Experimental studies on temperature depression measurements in individual points within cavitating flow were performed by Fruman et al. [5] and Franc et al. [6]. Rimbert et al. [7] presented experimental data of temperature depression in micro-channel cavitation with two-colors laser in several individual points, while Petkovšek & Dular [8] presented the first 2D temperature field of the cavitating flow on a small Venturi geometry with a non-invasive IR method. Dular & Coutier-Delgosha [9] used IR method to investigate thermodynamic effects on a single cavitation bubble.

Due to lack of the temperature experimental data within a cavitating flow, the improvement of the cavitation numerical models, with thermodynamic effects consideration, can not progress. To fill up the void in cavitation temperature database, the present study is performed.

2. Experimental set-up

Cavitation tests were performed in a cavitation tunnel at the Laboratory for Water and Turbine machines, University of Ljubljana.

The cavitation tunnel (Fig. 1 - left) has a closed circuit which enables to vary the system pressure and the temperature of the used liquid, water in our case. Circulation of the water is obtained with 4.5 kW pump (1), that enables the variation of the rotation frequency in order to set the flow rate. At the pump delivery, a tank (2) partially filled with the circulation water is used for water heating, 10 kW electric heater is installed, and for damping the periodical flow rate and pressure fluctuations due to the passage of the pump blades. Cavitation and thermodynamic effects are observed in a transparent polycarbonate test section (3). The tank downstream of the test section (4) is used for cooling of the circulation water, cooling water flows inside the tank in a secondary loop, which is connected to cold tap water. The temperature of the water is monitored with a Pt100 sensor (5) installed in the downstream tank and with a thermocouple J type directly installed in the test section. The pressure inside the cavitation tunnel can be varied with a vacuum pump connected to the downstream tank or with a compressor connected to the upstream tank in order to provide a wide range of hydrodynamic conditions. The flow rate is monitored with electromagnetic flowmeter (6).

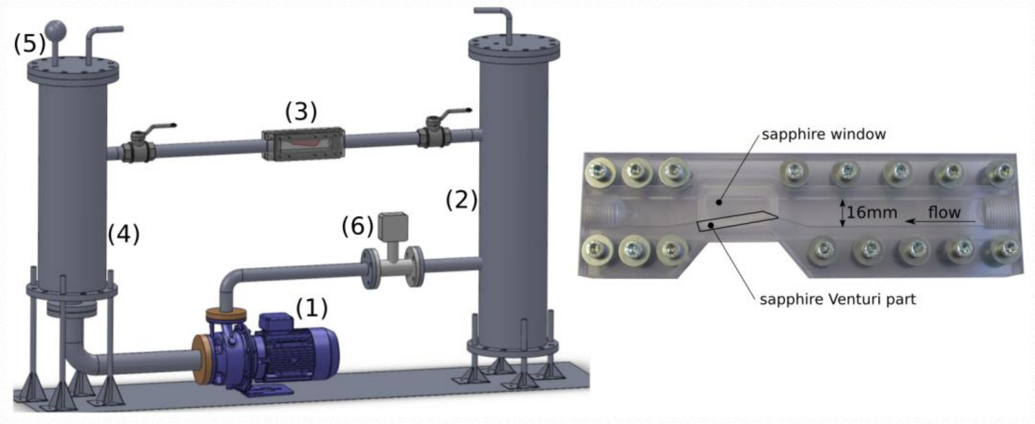

Figure 1: Cavitation tunnel (left), test section (right).

Specially designed test section (Fig. 1 - right), constructed out of transparent polycarbonate and sapphire glass, enables to withstand temperatures up to 120°C. Side window and part of Venturi are manufactured from sapphire glass, which enables visualization with conventional high-speed camera and thermography with IR high-speed camera. Side window allows to observe cavitation conditions from the side view, while part of Venturi constriction (part made out of sapphire, which serves as observation window) allows the view from below. The basic geometry was a 10 mm wide Venturi section with a converging angle of 18° and diverging angle of 8°. The throat cross-section dimensions were 8x10 mm^2.

To observe cavitation phenomena, two different camera positions were set. First, where the cameras (conventional high-speed camera and IR high-speed camera) were pointed into the side observation window and second, where cameras were pointed into bottom part of Venturi. In both cases the IR camera was perpendicular to observation surface, while the conventional camera was slightly at an angle to the IR camera.

3. Results and discussion

As mentioned, two types of measurements were conducted, where the thermodynamic effects were investigated from both the side and the bottom view of Venturi profile. In both observation positions, average temperature fields and temperature dynamics were observed at different cavitating conditions. All measurements were performed with tap water at approximately 100°C ± 2°C. For presented results the conventional high-speed camera operated at 10,000 fps, while IR camera operated at 830 and 920 fps for side and bottom view, respectively.

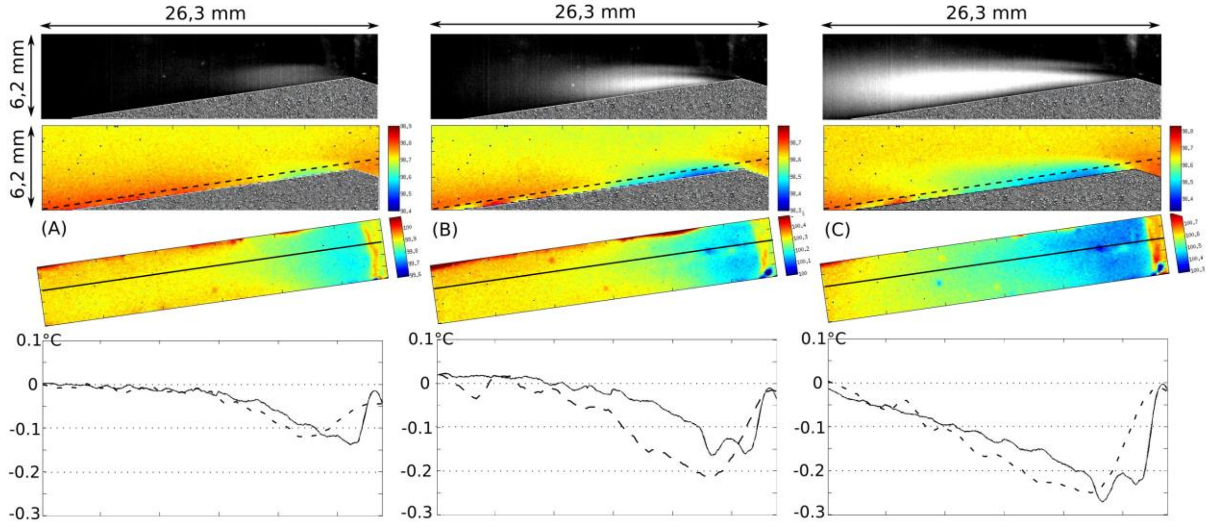

Figure 2: Average temperature fields for three different cavitation lengths (upper images), from side (middle images) and bottom view (bottom images). In diagrams are temperature collected from lines shown on upper temperature fields.

Figure 2 shows averaged visualization and temperature fields for the time of 1 second. The flow in presented cases goes from right to left, where the highest velocities, at the Venturi throat were between 9 m/s and 12 m/s. Images from visualization and thermography are scaled to show the same area of interest, but one must be aware, that temperature fields, which are shown on figure 2, the side view and the bottom view are not taken simultaneously. The cases were chosen from a set of measurements at different operating conditions (to chose different cavitation extent – cases A, B and C on fig. 2), where approximately the same conditions were chosen for the side and bottom view.

One can see, that in all three cases the temperature of the fluid flow starts to decrease just after the Venturi throat, due to vaporization and gas expansion, where the cavitation structures start to form. The temperature decrease for presented cases is between 0.12 K and 0.27 K, which corresponds with the results from the experiments of the Petkovšek & Dular [8] at the much smaller Venturi test section. One must be aware, that this are averaged temperature depressions and that the local temperature variations can reach up to 0.5 K in our observations. After the temperature decrease the temperature of the fluid flow returns to the initial free stream temperature. No obvious temperature increase above the free stream temperature is noticed. The magnitude and extent of temperature depression is increased with cavitation extent, as it is shown on figure 2. This means, that bigger cavitation extent cause stronger temperature depression of the flow.

Observing individual temperature fields on figure 3 gives us more thorough insight into the temperature dynamics. Figure 3 presents a short section of bottom view thermography from the case C, on fig. 2. The time step between the images is 1.1 ms. By moving along the images (fig. 3), one can see that the cold region left of the Venturi throat line is growing from image 1 to its maximum extent on image 6. After reaching its maximum extent, the cold region starts to shrinking back to to Venturi throat line. This corresponds to the cloud shedding. The smaller colder regions inside the cold region are most probably parts of cavitation cloud, which are moving closer to the Venturi channel bottom wall (observation window). Due to strong reverse flow, which appears in the Venturi test section and causes a thicker boundary layer between the observation window and observed cavitation structures, we believe, that actual temperature depression could be even higher.

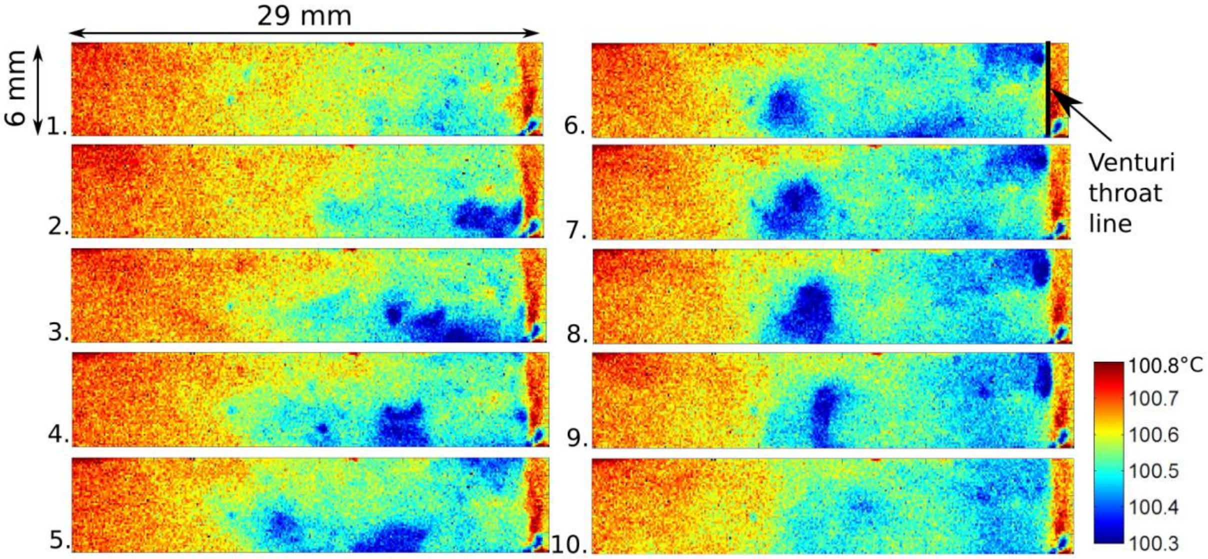

Figure 3: Bottom view temperature field for case of one cavitation cloud shedding.

4. Conclusions

The study presents a continuation of the previous work, Petkovšek & Dular [8], where the thermodynamic effects were observed in much smaller Venturi geometry. Scientific contribution is not just in scaling up the test section, but also that for the first time the thermodynamic effects were observed from the bottom view of the Venturi geometry. It was shown that the temperature depression, due to cavitation, can be measurable already in water of 100°C, by which conditions our experiments were performed.

Acknowledgments

The study was performed under a grant by the European Space Agency (ESA).

References

[1] Hord J, Anderson M, Hall W J 1972 NASA CR-2054.
[2] Hord J 1972 NASA CR-2156.
[3] Hord J 1973 NASA CR-2242.
[4] Hord J 1974 NASA CR-2448.
[5] Fruman D H, Reboud J L 1999 *Int. J. of Heat and Mass Transfer* 42, 3195-3204.
[6] Franc J P, Boitel G, Riondet M, Janson E, Ramina P, Rebattet C 2010 *J. of Fluid Engineering* 132, 1-9.
[7] Rimbert N, Castanet G, Funfschiling D 2012 *Proc. of the 8th Int. Sym. On Cav. CAV2012, Singapure*.
[8] Petkovšek M and Dular M 2013 *Int. J. of Heat and Fluid Flow* 44, 756-763.
[9] Dular M and Coutier-Delgosha O 2013 *J. Fluid Mech.* 736, 44-66.